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MINIMUM IGNITION TEMPERATURE: AN ALTERNATIVE SMALL-SCALE FLAMMABILITY TEST FOR CONVEYOR BELTING

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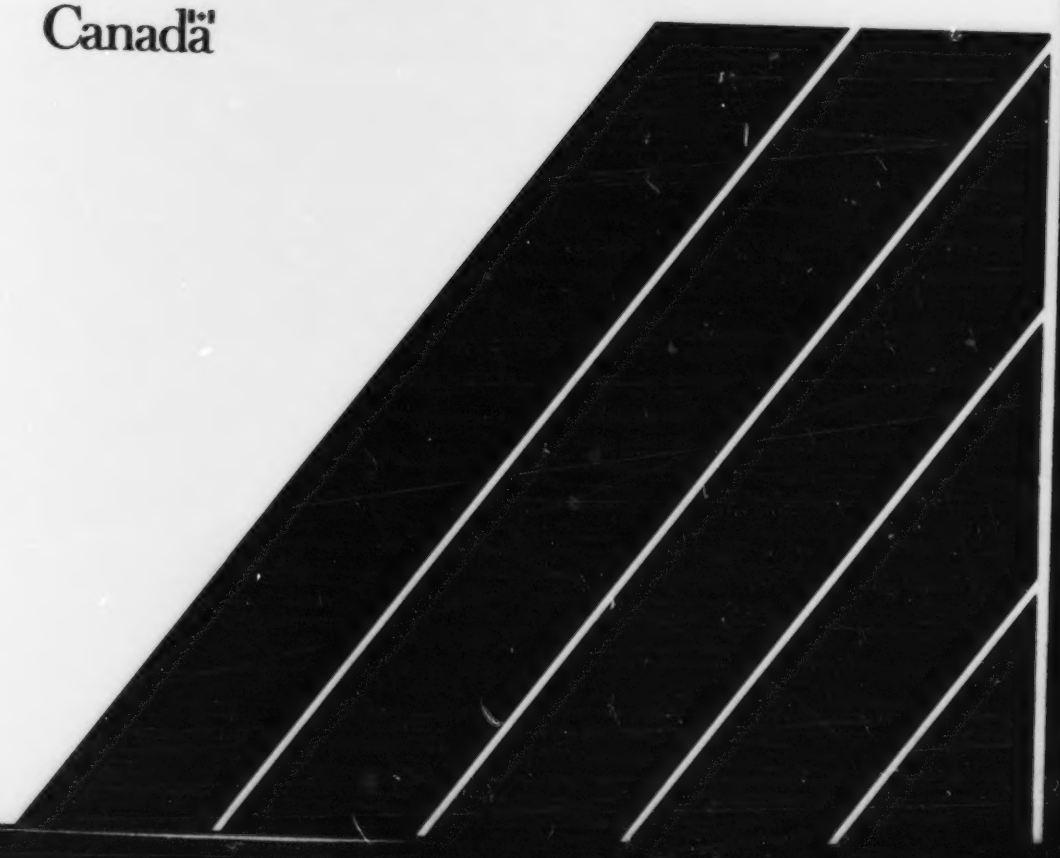

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by

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ABSTRACT

Minimum ignition temperature (MIT) tests were carried out on 10 different conveyor beltings to determine if this test is useful for assessing the fire-resistance of belting. In all but one case, two different MIT values were obtained for each product: a lower one, in which an exothermic reaction was observed, designated $MIT_{non\text{-}fl}$, and a higher one, in which the sample burst into flames, designated MIT_{fl}. The correlation between these two parameters was poor, probably because of the different nature of fire-retardants incorporated into the various formulations. The correlation between both MIT's and the results of the large-scale tests is only fair; the oxygen index test proved to be a much better predictor of large-scale performance than either MIT, because both the oxygen index and large-scale tests measure primarily flame propagation, and the MIT's measure ignitability. The main usefulness of the MIT test would be to determine the ignitability of belting when exposed to a hot source.

KEYWORDS: conveyor belting, flammability, minimum ignition temperature

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TEMPÉRATURE MINIMALE D'INFLAMMATION: ESSAI DE RECHANGE PERMETTANT DE DÉTERMINER A PETITE ÉCHELLE L'INFLAMMABILITÉ DE BANDES TRANSPORTEUSES

par

K.J. Mintz* et K.V. Inglis**

RÉSUMÉ

Nous avons mesuré la température minimale d'inflammation (MIT) de 10 bandes transporteuses différentes, en vue de déterminer dans quelle mesure ce paramètre permet d'évaluer la résistance au feu de ces bandes. Dans tous les cas sauf un, deux valeurs différentes ont été obtenues pour la température minimale d'inflammation, soit une valeur inférieure, désignée par $MIT_{non\text{-}infl.}$, pour laquelle une réaction exothermique a été observée, et une value supérieure, désignée par $MIT_{infl.}$, correspondant à 'inflammation spontanée de l'échantillon. La corrélation entre ces deux paramètres n'était guère bonne, probablement en raison de la nature différente des ignifugeants incorporés dans les diverses formulations. La corrélation entre les deux valeurs de MIT et les résultats des essais à grande échelle n'était que moyenne; l'indice d'oxygène est un indicateur beaucoup plus utile de la performance à grande échelle mesurent principalement la propagation des flammes, tandis que la température minimale d'inflammation est une mesure d'inflammabilité. La température minimale d'inflammation est surtout utile pour déterminer l'inflammation des bandes transporteuses exposées à une source chaude.

MOTS CLÉS: bandes transporteuses, inflammabilité, température minimale d'inflammation

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INTRODUCTION

Fire-retardant conveyor belting is used widely in underground mines to decrease the probability of a disastrous fire, such as occurred in the Gaspé Copper Mine on April 1, 1987 (1). Standards to measure the fire-resistance of belting have been established in many countries; the degree of protection by them varies considerably. Canada recently developed a national standard which takes into account conditions particular to Canada (2). Types A and B of this standard are among the most stringent in the world; Type C provides for a much lower degree of protection and was included mainly to provide continuity with the ad hoc EMR specifications used until the CSA Standard was adopted.

The small-scale flame test in the Canadian Standard, along with other small-scale flame tests in other standards, suffers from a number of deficiencies, particularly that of reproducibility (3). A study was carried out in this laboratory on the long-term reproducibility of three small-scale tests: flame, oxygen index and surface ignition temperature (4). From the viewpoint of reproducibility, the oxygen index test was excellent.

The minimum ignition temperature (MIT) test is used as a measure of the flammability of pure plastics, and is described in a standard published by the American Society for Testing and Materials (5). It has apparently not been applied to testing the flammability of composite materials, such as conveyor belting. The purpose of the present study is to evaluate the usefulness of the MIT test for conveyor belting and compare the results with other flammability data.

Several years ago, a crude version of the MIT apparatus was set up in this laboratory as part of a study of the flammability of a polyethylene idler roll proposed for use in a potash mine (6). The low value of MIT obtained, along with low values of oxygen index and hot-plate ignition temperature, compared with non fire-

resistant conveyor belting, led to the rejection of this idler roll. On the basis of the usefulness of MIT in that study, a decision was made to purchase the standard equipment for measuring the MIT.

As it turned out, the apparatus was first used for examining the flammability of dust that had been believed to be the cause of a fire in a chemical factory. By this means, this dust was proven to be incombustible. Later, a study of the MIT of dust layers (using "standard" combustible dusts) showed that there were two distinct values of MIT for each dust: an $MIT_{non\text{-}fl}$, in which the sample decomposed exothermically, but without flames, and an MIT_{fl}, in which the sample bursts into flames (7). The latter, of course, occurs at a substantially higher temperature. It is of interest to determine if the same phenomenon occurs for conveyor belting.

APPARATUS

The MIT apparatus, also known as the Setchkin furnace, is described in ASTM Standard D1979 (5). The furnace consists of an inner ceramic tube of inside diameter 76 mm and length of about 220 mm, which is inside another ceramic tube, containing the heating unit. The unit is placed so that the tubes are vertical; air flows down the outer tube and up the inner tube. The top is covered by a split disk made of Pyrex glass with a 25 mm diameter opening.

The unit used here was made by Custom Scientific Instruments, Inc., Cedar Knolls, N.J. and consists of the furnace itself plus a control unit. The latter contains a pump and flowmeter for the supply of compressed air for the furnace, heating controls and a data logger (dot-matrix printer). The latter is pre-programmed (not user-adjustable) so that it prints out temperatures from five K-type thermocouples every minute and charts the temperatures every 10 s. One thermocouple, used for control, is installed in the outer tube.

In order to see events occurring in the sample, a holder for a mirror was built and attached to a metal support positioned appropriately.

Two thermocouples are required for the tests (in addition to the control thermocouple): one positioned below the sample, which measures the furnace temperature, and the other, which is positioned touching the sample. The thermocouples used were the sealed and grounded type, 3.2 mm in diameter. Exposed-end thermocouples were supplied with the instrument, but they did not survive the corrosive gases generated during the tests. The accuracy of the thermocouples was checked with a thermocouple calibrator; the maximum deviation in the range 100 - 500°C was ± 3°C. Because the decomposition of the conveyor belting produces sticky material, the ends of the sample thermocouple had to be cleaned frequently.

The sample container used was a ceramic crucible (Coors Model 60133), which has a diameter of 32 mm and a height of 20 mm. It fits into a stainless steel ring of 35 mm diameter, which was welded onto a stainless steel rod 190 mm long, with a hook on the end to fit over a support rod 30 mm above the top of the furnace.

PROCEDURE

A detailed examination of the Setchkin furnace was recently carried out in connection with commissioning it for measuring the minimum ignition temperatures of dust layers (7). A detailed procedure was also given; the same procedure was followed in the present study, with the exception that the sample size was 3 ± .5 g, in accordance with the ASTM Standard. For each product, the "rising temperature" method was carried out first to give a rough value of the $MIT_{non\text{-}fl}$, then constant temperature tests were carried out to determine the value within ± 10°C, the estimated accuracy of the apparatus. The MIT_{fl} was determined by starting off

at a much higher temperature, certain to produce a flame, then carrying out subsequent trials at successively lower temperatures until no flame was produced. The flow rate of air through the furnace for all the trials was maintained at 10 SCFH, which corresponds to an air velocity in the furnace of 3.5 - 4.5 cm/s in the temperature range used.

Ten samples were tested; nine of which had been tested by the U.S. Bureau of Mines in their large-scale facility at Lake Lynn in addition to oxygen index tests at the U.S. Bureau of Mines and CANMET. The designation of samples are those of the U.S. Bureau of Mines: R-1, R-2, R-3, R-4, R-9, R-10, P-1, P-2, P-3. The "R" refers to rubber belting; the "P" refers to polyvinylchloride (PVC) belting. The remaining sample is designated R-x.

RESULTS

Sample R-1

R-1 is a one-ply belting of thickness 10.4 mm. In the rising temperature test, smoke was observed at about 250°C, with a dense black cloud of smoke produced at about 360°C. At about that temperature, the reading of the sample thermocouple, which had been close to the furnace thermocouple up to then, started increasing rapidly. The test was terminated about four minutes later and the sample removed. It appeared to be almost totally burnt and was still glowing red.

The results of the four constant temperature trials are shown in Table 1[1]. In all cases, smoke was produced and the sample puffed up, with melting of the carcass. The second column indicates the time that smoke appeared. As would be expected, the

[1] The order of trials was different from that given in the tables, which is given in ascending order of initial temperature so as to be able to see the trends easier.

higher the initial temperature, the sooner smoke appeared. In the case of trial #4, there was very dark smoke produced, and the surface of the sample afterwards was very crumbly. Figure 1 shows the temperature traces for the four trials. Time zero was chosen to be the time that the sample was placed into the furnace. During the next minute or so, the temperature drops sharply, because some cooler air unavoidably enters the furnace. Then the temperature slowly climbs. For the lower three curves, the temperature stabilizes approximately to the original temperature, after about 10 - 15 minutes. The upper curve, on the other hand, shows an inflection point at about 8 min., and reaches a temperature significantly higher than the original. Hence, the MIT is bracketed between the two upper curves. In order not to exaggerate the accuracy of the method, the $MIT_{non\text{-}fl}$ is taken as 330 ± 10°C, which is somewhat below the estimate of 360°C from the rising temperature method.

For the determination of MIT_{fl}, a stopwatch was used to measure the time between the sample being placed in the furnace and the appearance of flames. The temperature recorder showed the same initial drop in temperature as in the $MIT_{non\text{-}fl}$ determination, but the recovery is interrupted by massive irregularities, which correspond to the beginning of the flames. The data is shown in Table 2; the resultant value of MIT_{fl} is 420 ± 10°C.

Table 1. $MIT_{non\text{-}fl}$ tests on Sample R-1

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
324	3.8	340	--
328	3.5	346	--
330	3.5	341	--
334	2.5	367	342

Table 2. MIT_{fl} tests on Sample R-1

Initial Temperature (°C)	Time to flame (min.)
452	3.2
443	3.7
439	4.3
438	4.4
425	6.1
419	--

Sample R-2

R-2 is a four-ply belting of thickness 14.2 mm. The rising temperature trial yielded smoke at about 235°C, and heavy smoke at about 320°C. At the end of the trial, the sample was burnt, puffed up, and the plies opened up. Based on the three constant temperature trials (Table 3), the MIT of sample R-2 is 280 ± 10°C. The time of appearance of smoke did not follow the trend; however, the temperature range was quite small. The $MIT_{non\text{-}fl}$ was again somewhat below the temperature at which heavy smoke appeared in the rising temperature trial. From Table 4, the MIT_{fl} is 450 ± 10°C.

Table 3. $MIT_{non\text{-}fl}$ tests on Sample R-2

Initial Temp. (°C)	time to smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
275	3.5	280	--
280	4.5	293	278
283	4.3	303	282

Table 4. MIT_{fl} tests on Sample R-2

Initial Temperature (°C)	Time to flame (min.)
494	1.8
483	1.5
474	2.2
473	2.5
455	2.6
447	--

Sample R-3

Sample R-3 had the same construction as R-2, i.e. four plies and a thickness of 14.2 mm. The rising temperature trial yielded smoke at about 240°C and heavy smoke at about 320°C. The constant temperature trials (Table 5), although they showed inflection points at lower temperatures than R-2, required longer times to reach them (roughly 15 min. vs. 5 min.). The $MIT_{non\text{-}fl}$ of R-3 is 230 ± 10°C. Table 6 shows the results of the trials for MIT_{fl}; its value is 440 ± 10°C, the same as for sample R-2, even though the $MIT_{non\text{-}fl}$ is substantially lower.

Table 5. $MIT_{non\text{-}fl}$ tests on Sample R-3

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
229	10	240	--
236	10	250	241
243	7	255	255

Table 6. MIT_{fl} tests on Sample R-3

Initial Temperature (°C)	Time to flame (min.)
497	2.0
486	2.2
471	2.5
462	2.5
438	3.0
434	--

Sample R-4

R-4 was a solid-woven belting of thickness 9.3 mm. In the rising temperature trial, smoke appeared at about 280°C, somewhat higher than for the previous samples. The sample continued to glow upon removal from the furnace. The MIT_{non-fl} was 370 ± 10°C (see Table 7). The MIT_{fl} was 570 ± 10°C (see Table 8), much higher than for previous samples. Note that there is a sharper cut-off for the occurrence of a flame with respect to the time to the flame. This may show the effectiveness of flame-retardants in the formulation.

Table 7. MIT_{non-fl} tests on Sample R-4

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
260	19	265	--
266	14	270	--
363	3.8	384	--
376	3.7	435	357
388	3.0	452	372
391	2.6	410	389

Table 8. MIT_{fl} tests on Sample R-4

Initial Temperature (°C)	Time to flame (min.)
594	1.1
586	1.1
575	1.8
567	1.2
561	--
543	--

Sample R-9

Sample R-9 was a 3-ply belting of thickness 9.5 mm. The rising temperature trial produced smoke starting at about 290°C, with more dense smoke appearing at about 380°C. Table 9 indicates that the $MIT_{non\text{-}fl}$ is 400 ± 10°C. In the trials in which there was no inflection point, the samples were puffed up and cracked; for the trials that had inflection points, the pieces were just char. From Table 10, the MIT_{fl} is 490 ± 10°C.

Table 9. $MIT_{non\text{-}fl}$ tests on Sample R-9

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
366	4	380	--
379	3	389	--
397	2	411	--
404	2	449	379
413	2.7	483	375
424	2.3	452	390

Table 10. MIT_{fl} tests on Sample R-9

Initial Temperature (°C)	Time to flame (min.)
493	2.7
491	4.9
481	--
433	--

Sample R-10

Sample R-10 was a single-ply belting of thickness 8.5 mm. In two rising temperature trials, smoke started appearing at about 260 and 275°C; heavy smoke started at about 360°C. From Table 11, the $MIT_{non\text{-}fl}$ is 380 ± 10°C. From Table 12, the MIT_{fl} is 490 ± 15°C.

Table 11. $MIT_{non\text{-}fl}$ tests on Sample R-10

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
322	4	331	--
338	3	350	--
358	3	363	--
376	3	391	--
387	2.0	>421	386
395	2.5	421	393

Table 12. MIT_{fl} tests on Sample R-10

Initial Temperature (°C)	Time to flame (min.)
499	2.1
492	2.3
475	--
456	--

Sample P-1

Sample P-1 had a total thickness of 11.1 mm, with only approximately 1 mm on each side being the PVC cover layer. In the constant temperature trial, smoke began at about 244°C. The sample melted into a ball, in contrast to the rubber belting samples which puffed up. Table 13 indicates that the $MIT_{non\text{-}fl}$ is 370 ± 10°C. Table 14 indicates that the MIT_{fl} is 500 ± 10°C.

Table 13. $MIT_{non\text{-}fl}$ tests on Sample P-1

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
369	4	370	--
373	3.2	390	385
377	3	394	360

Table 14. MIT_{fl} tests on Sample P-1

Initial Temperature (°C)	Time to flame (min.)
501	2.4
491	--
458	--

Sample P-2

Sample P-2 was a PVC belting of total thickness 11.4 mm with covers of about 1 mm on each side. In the rising temperature trial, smoke started at about 295°C, significantly higher than for sample P-1. Instead of melting to a ball, the sample melted flat to the bottom of the crucible. In the constant temperature trials at the highest 5 temperatures, only white ashes were left. (The trials lasted approximately 30 minutes each.) In the remaining trials, the samples only melted. Table 15 indicates that the $MIT_{non\ fl}$ is 430 ± 10°C; Table 16 indicates that the MIT_{fl} is 510 ± 10°C.

Table 15. $MIT_{non\text{-}fl}$ tests on Sample P-2

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
365	3.0	368	--
484	2.2	387	--
411	2.0	414	--
435	2.0	447	--
438	1.9	480	457
449	1.5	477	456
452	1.5	469	453

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
456	1.5	475	464

Table 16. MIT_{fl} tests on Sample P-2

Initial Temperature (°C)	Time to flame (min.)
550	1.4
532	1.8
524	1.8
515	2.2
510	4.9
506	--
505	--

Sample P-3

Sample P-3 had a total thickness of 9.0 mm, and covers about 1 mm thick. The rising temperature trial yielded smoke at about 220°C. The sample was puffed up, unlike samples 1 and 2. The constant temperature tests yielded the highest value of $MIT_{non\text{-}fl}$, 460 ± 10°C (Table 17). However, the test at 464°C did not yield an actual inflection point, but rather the sample burst into flames. Therefore, no maximum temperature is recorded. Table 18 indicates that the MIT_{fl} is 470 ± 20°C, essentially the same as the $MIT_{non\text{-}fl}$, which is not surprising, since the latter actually produced flames.

Table 17. $MIT_{non\text{-}fl}$ tests on Sample P-3

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
368	5.5	377	--
372	2.0	379	--
383	2.0	391	--
394	2.0	400	--
404	1.3	410	--
413	1.1	421	--
424	1.5	429	--
433	1.0	446	--
444	1.0	454	--
449	1.0	462	--
464	<1.0	--	460

Table 18. MIT_{fl} tests on Sample P-3

Initial Temperature (°C)	Time to flame (min.)
505	3.5
495	2.2
456	--

Sample R-x

Sample R-x is a single-ply belting of total thickness 10.4 mm, with the pulley side 2 mm thick and the carrying side 6 mm thick. In the rising temperature trial, smoke started appearing at 223°C. In the lowest constant temperature trial, the sample did not change

in appearance; in the other trials, the samples became puffed up, the covers became brittle and cracked and the carcass melted. From Table 19, the $MIT_{non\text{-}fl}$ is 230 ± 10°C; from Table 20, the MIT_{fl} is 410 ± 10°C.

Table 19. $MIT_{non\text{-}fl}$ tests on Sample R-x

Initial Temp. (°C)	t-Smoke (min.)	Maximum Temp. (°C)	Inflection Temp. (°C)
189	--	194	--
219	12	227	--
225	11.6	245	--
236	10	256	239

Table 20. MIT_{fl} tests on Sample R-x

Initial Temperature (°C)	Time to flame (min.)
415	3.0
412	4.7
402	--

DISCUSSION

Figure 2 shows the comparison of the MIT_{fl} and $MIT_{non\text{-}fl}$ results, with the least-squares line drawn. As can be seen, the correlation of the two parameters is not good: the coefficient of correlation is only 0.61. In fact, one can not reject, at the 95% probability level, the null hypothesis that the slope of the line is zero, i.e. that there is no relationship. The $MIT_{non\text{-}fl}$ is the temperature at which an exothermic decomposition began to occur. The MIT_{fl} is the temperature at which there is sufficient flammable gas concentration, produced by the decomposition of the belting, to

spontaneously ignite. Depending on the fire-retardant system used, the exothermic reaction (solid phase) or the spontaneous ignition (gas phase) can be suppressed. Thus, if the former applies, then the $MIT_{non\text{-}fl}$ would be raised above that of a belting of similar composition, but without fire-retardants; if the latter applies, then the MIT_{fl} would be similarly raised. R-1 is a non fire-resistant belting; it is of interest to note that three beltings have a lower $MIT_{non\text{-}fl}$ than R-1. This may possibly be attributed to an exothermic decomposition of fire-retardants occurring at relatively low temperatures. These three beltings all failed the larger-scale tests, indicating that their fire-retardant systems are inadequate.

The relationship between the $MIT_{non\text{-}fl}$ and oxygen index measured by CANMET (Table 21) is shown in Fig. 3. The coefficient of correlation is only 0.60; the null hypothesis that the slope of the least-squares line is non-zero cannot be rejected, at the 95% level. The MIT_{fl} vs. oxygen index (Fig. 4) has a higher coefficient of correlation, 0.72; the null hypothesis can be rejected, i.e. there is a definite relationship. However, the substantial scatter in Fig. 4, well outside the experimental uncertainties, indicates that the MIT_{fl}, as well as the $MIT_{non\text{-}fl}$, is measuring different flammability characteristics of the beltings.

The U.S Bureau of Mines has carried out an extensive series of tests on the flammability of conveyor belting, both on a full-scale basis in their experimental mine and in a laboratory apparatus, which will be referred to here as a mid-scale apparatus (7). The agreement obtained was good: 15/17, based on the pass/fail criteria. Nine of these beltings were used in the present study, as shown in Table 21. Five of the six CANMET propane gallery (flame propagation) tests were in agreement with the large-scale tests; the remaining one was a marginal pass in the propane gallery test but a fail in both the mid-scale and large-scale tests.

Table 21. Results from five different flammability tests

	Large-scale	Mid-scale	Propane gallery	Oxygen Index		MIT_{non-fl}	MIT_{fl}
	USBM	USBM	CANMET	USBM	CANMET	CANMET	CANMET
R-1	Fail	Fail	--	22.2	22.7	330	420
R-2	Fail	Fail	--	25.6	27.2	280	470
R-3	Fail	Fail	--	24.9	25.9	230	440
R-4	Pass	Pass	Pass	33.4	35.2	370	570
R-9	Fail	Fail	Fail	32.7	35.4	400	490
R-10	Pass	Pass	Pass	32.2	32.7	380	490
P-1	Fail	Fail	--	26.5	27.8	370	500
P-2	Fail	Fail	Pass(marginal)	27.1	28.1	430	510
P-3	Pass	Pass	Pass	31.2	32.9	460	470
R-x	--	--	Fail	--	26.3	230	410

Figures 5 - 7 show graphically, the relationship between the results of the large-scale tests and MIT_{non-fl}, MIT_{fl} and oxygen index, respectively[2]. Although there is certainly a tendency for higher MIT's to be associated with passes, there is considerable overlap. Hence, the predictive power of MIT's appear to be rather limited. The MIT's are associated with the propensity to ignition, the mid- and large-scale tests are associated more with flame propagation; thus they measure different properties in the general category of "fire-resistance".

Except for one point, the oxygen index shows a clear separation between passes and failures in the large-scale test. The odd-one out is R-9, which, according to the U.S. Bureau of Mines (7) had the same covers as R-10, but had a carcass consisting of three plies, compared to a solid woven carcass used in R-10.

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[2]Sample R-x was not tested by the U.S. Bureau of Mines; however, based on its failure in the propane gallery test, it seems safe to include it as a fail in Fig. 5 - 7. The oxygen index results have not been reported previously.

Ply belts sometimes de-layer while burning, which greatly increases the exposed surface area, thus increasing the rate of burning. This effect is usually observed during oxygen index tests as well as in large-scale tests, but in the particular case of R-9, the covers are so fire-resistant that this effect can only be observed in mid- or large-scale tests. A study of the long-term reproducibility of oxygen index tests (on different products from those studied here) demonstrated that this test would be useful for quality control purposes (4). The current study reinforces that oxygen index is the small-scale test of choice.

CONCLUSIONS

Minimum ignition temperature measurements of conveyor belting, whether non-flaming or flaming, appear not to provide an adequate predictor of performance in large-scale flame propagation tests, because the MIT tests measures primarily ignitability. In contrast, oxygen index tests appear to be useful for prediction of large-scale tests. However, the correlation between oxygen index and large or mid-scale tests is not perfect; oxygen index should not be used as a test for certification, but only for quality control and for screening potential formulations. The MIT test can be used for other purposes, for example, measuring the resistance of belting and other materials used in underground mines to hot materials, determining the ignitability of belting by heat sources as part of an accident investigation, etc.

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Fig.1. MIT Tests on Sample R-1

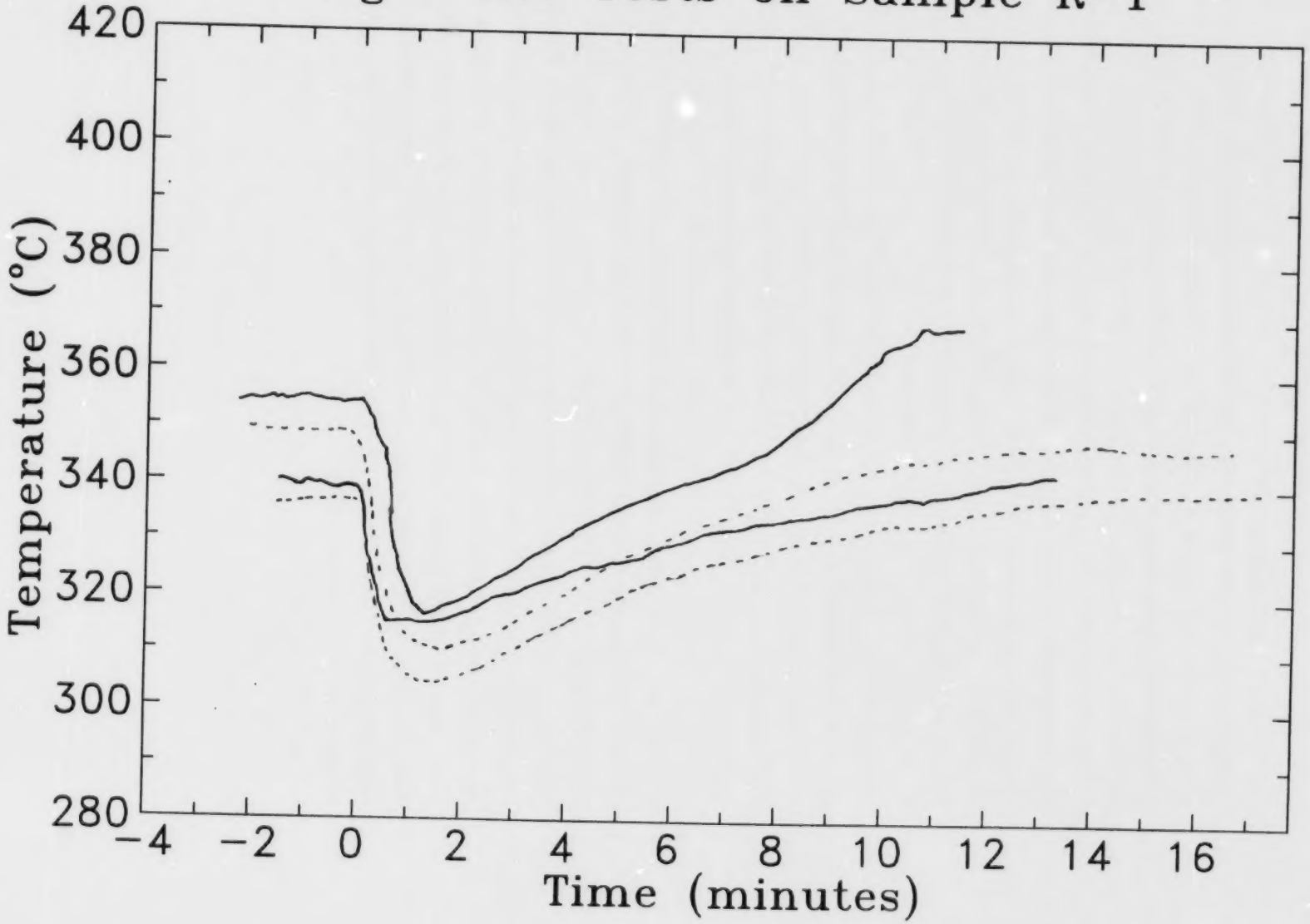

Fig.2. MIT_{fl} vs. MIT_{non-fl} for Conveyor Belting

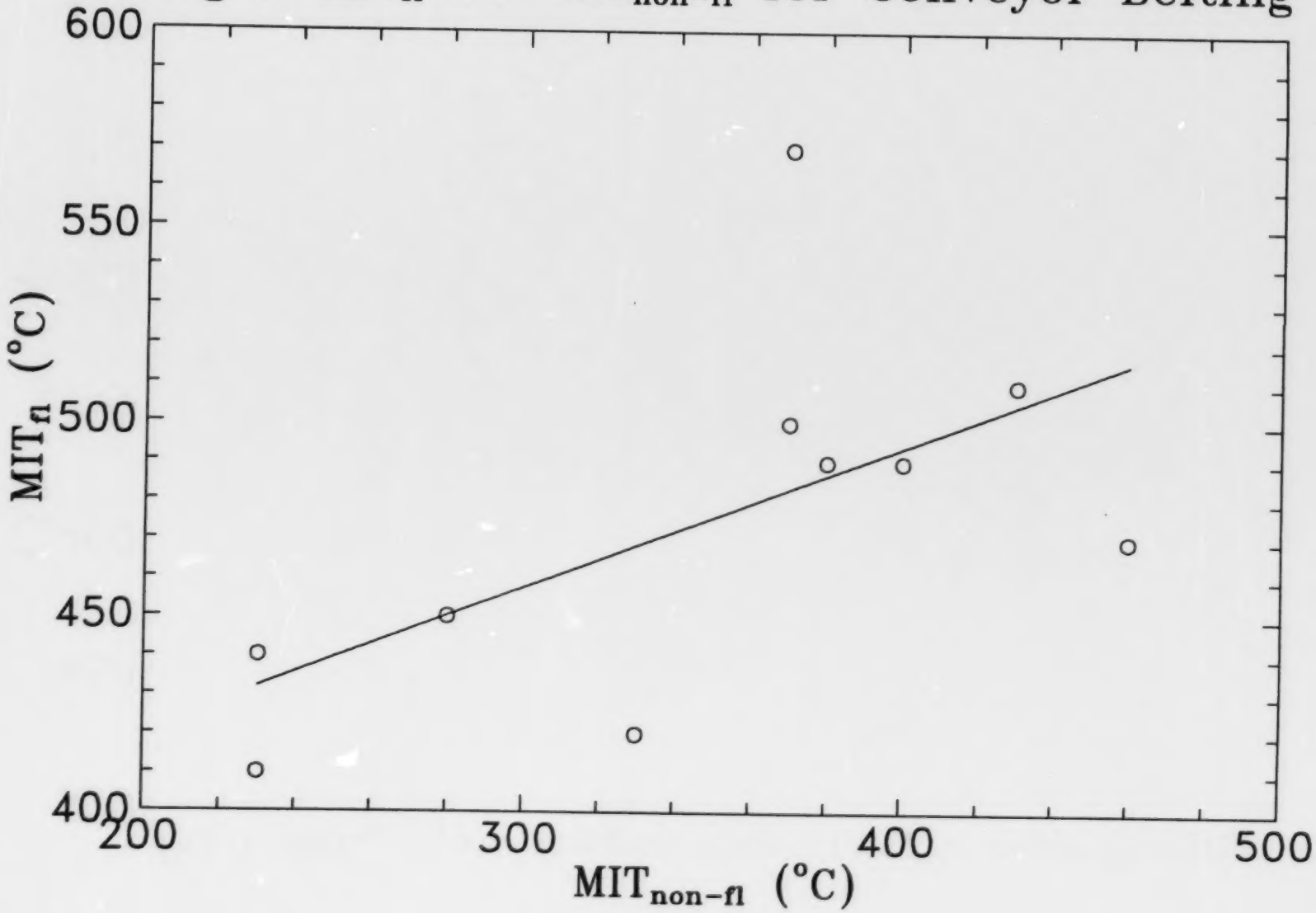

Fig.3. MIT_{non-fl} vs. Oxygen Index for Conveyor Belting

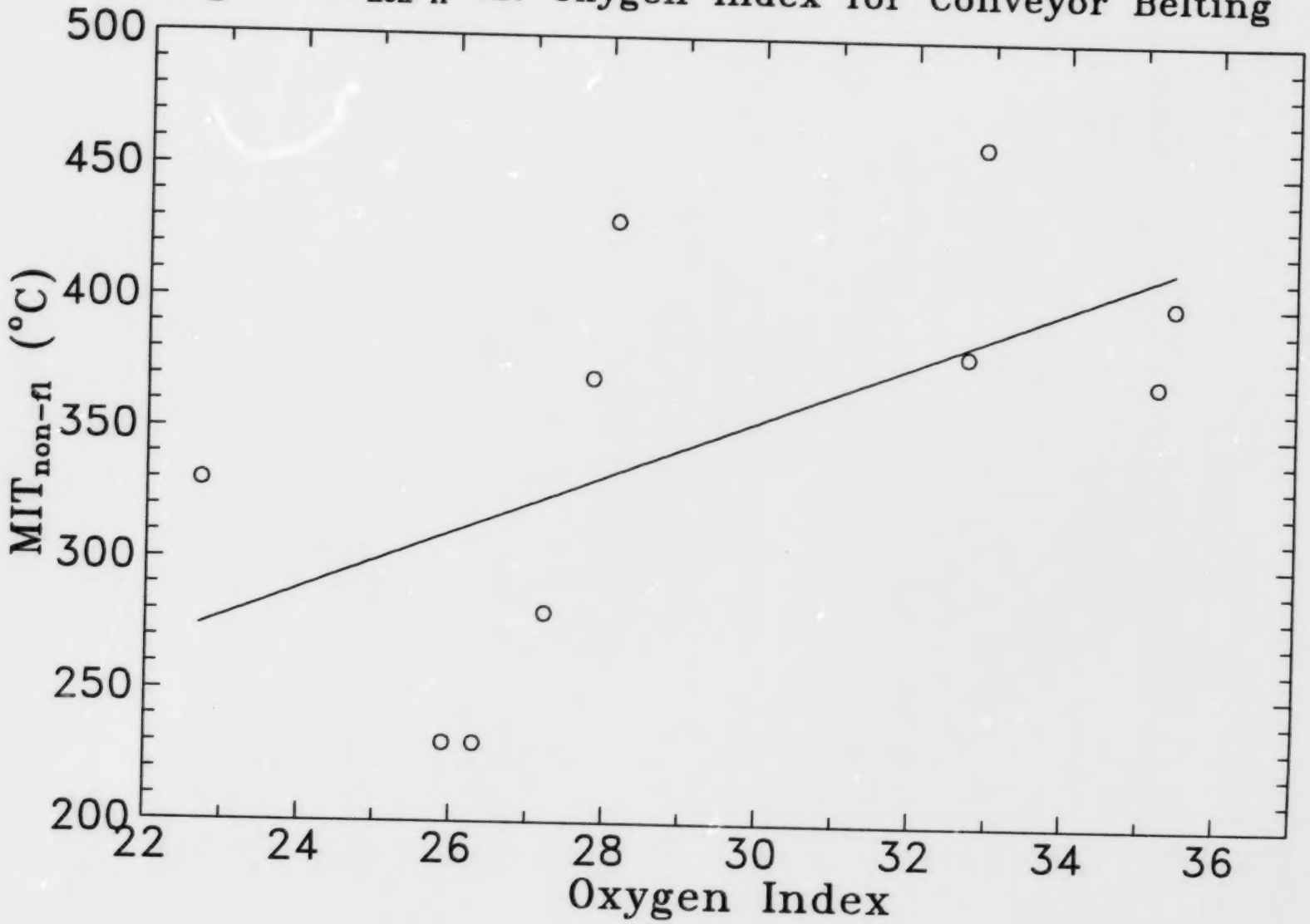

Fig.4. MIT_n vs. Oxygen Index for Conveyor Belting

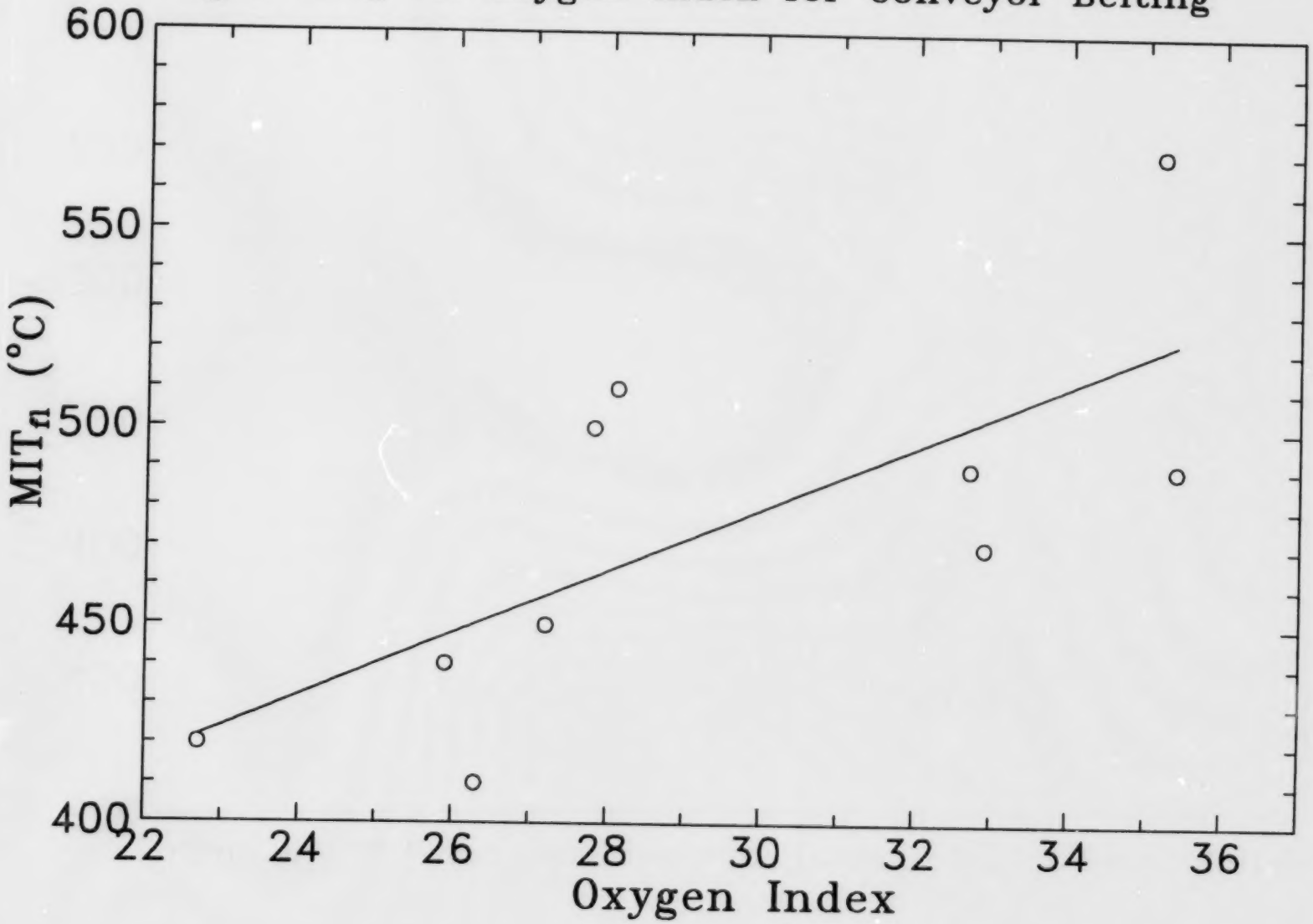

Fig.5. MIT_{non-fl} vs. Large-scale Tests on Conveyor Belting

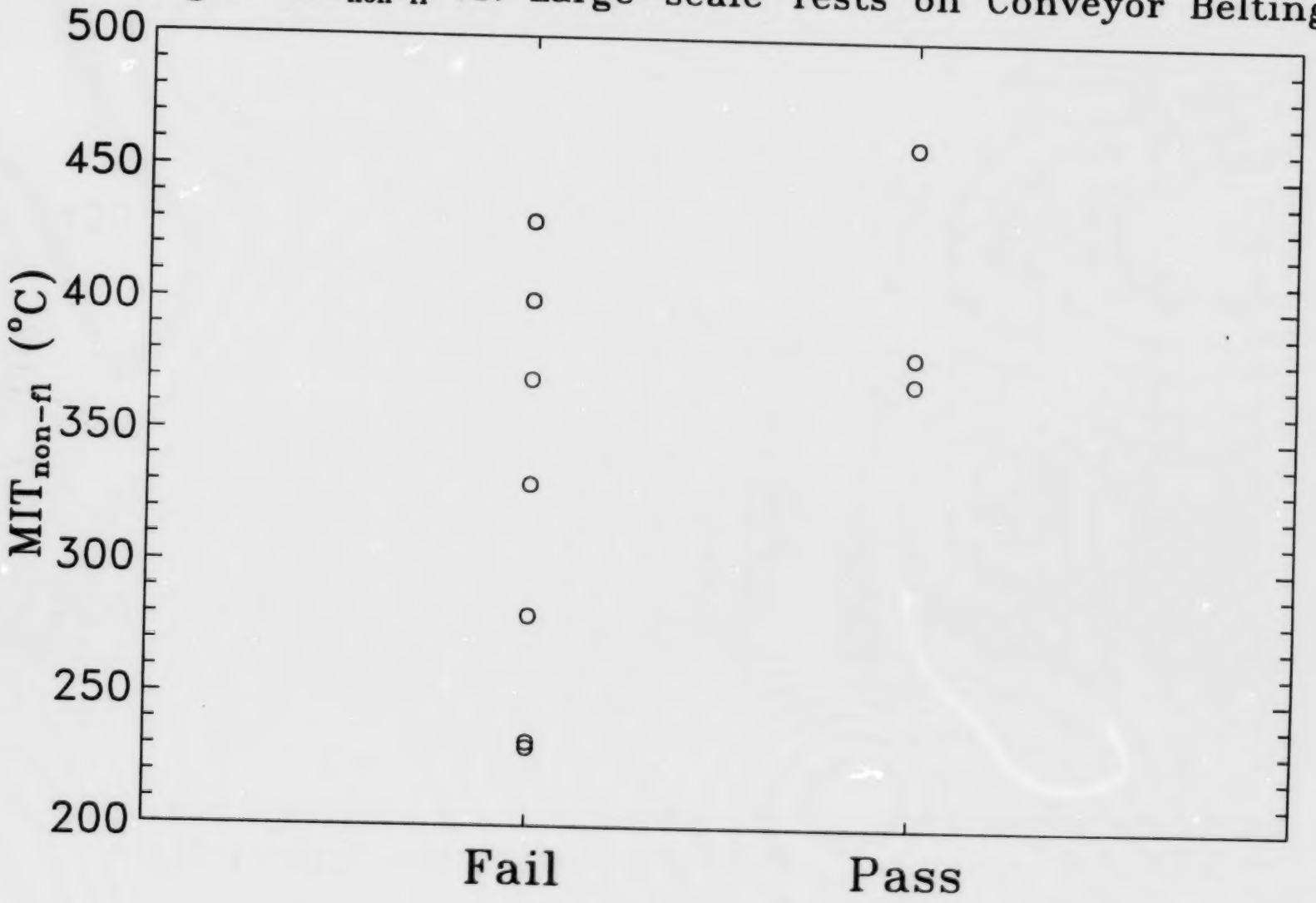

Fig.6. MIT_{fl} vs. Large-scale Tests on Conveyor Belting

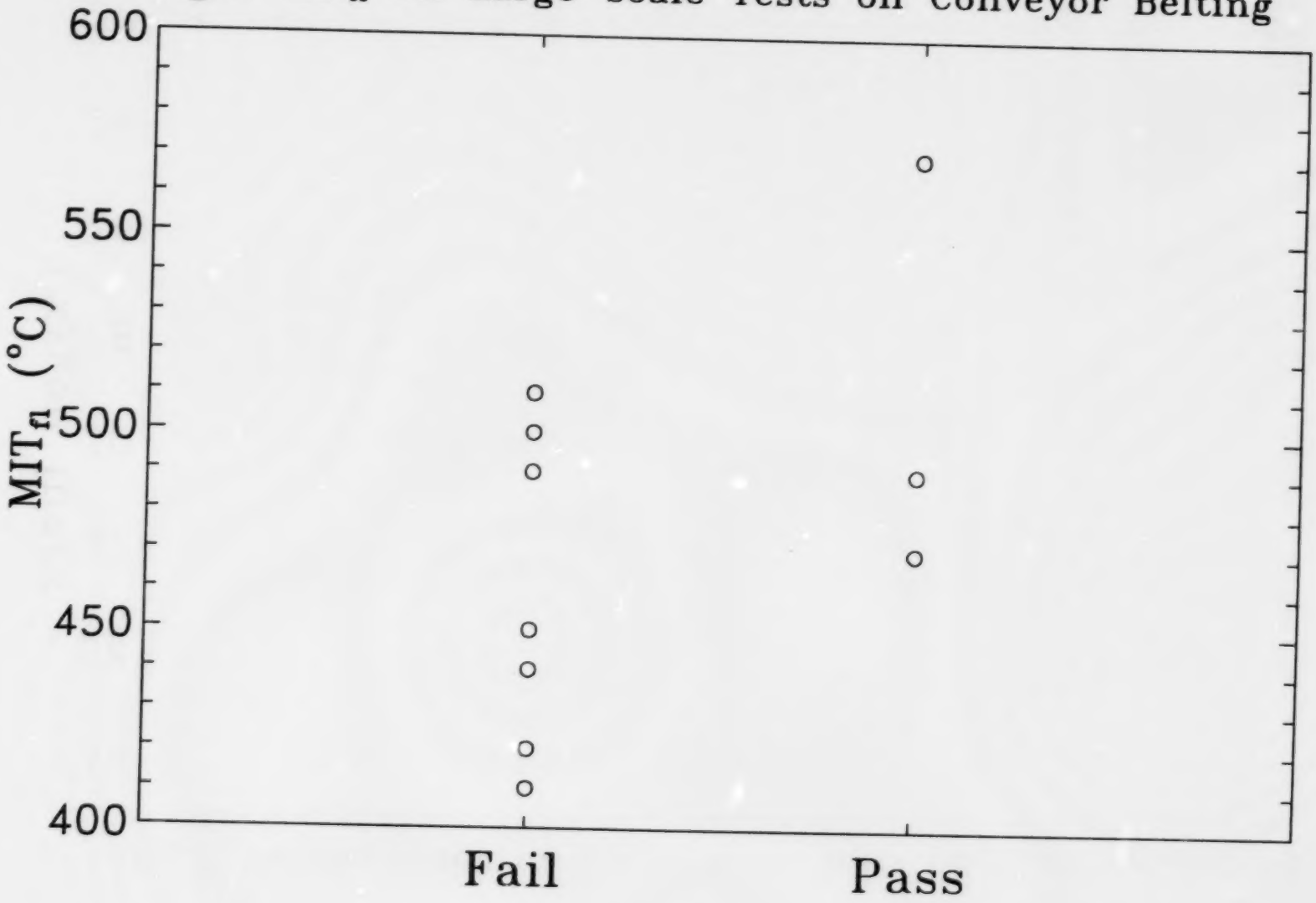

Fig.7. Oxygen Index vs. Large-scale Tests on Conveyor Belting